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## NASA Dryden Flight Research Center

### "Maximum Thrust Mode Evaluation"

#### Table of Contents

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Navigating Around the Workshop:

[[Workshop Home](#)] [[Session Agenda](#)] [[Submit Response / Read Responses](#)]

**HELP** is Available

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#### CONTENTS:

- [Prediction of a Maximum Thrust Mode Acceleration \(p. 1\)](#)
  - [Maximum Thrust Mode Predictions \(p. 2\)](#)
  - [Maximum Thrust Mode Analysis \(p. 3\)](#)
  - [Maximum Thrust Mode Analysis \(contd.\) \(p. 4\)](#)
  - [Summary of Results for the Maximum Thrust Mode \(p. 5\)](#)
  - [Summary of Results for the Maximum Thrust Mode \(contd.\) \(p. 6\)](#)
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## NASA Dryden Flight Research Center

"Maximum Thrust Mode Evaluation", page 1

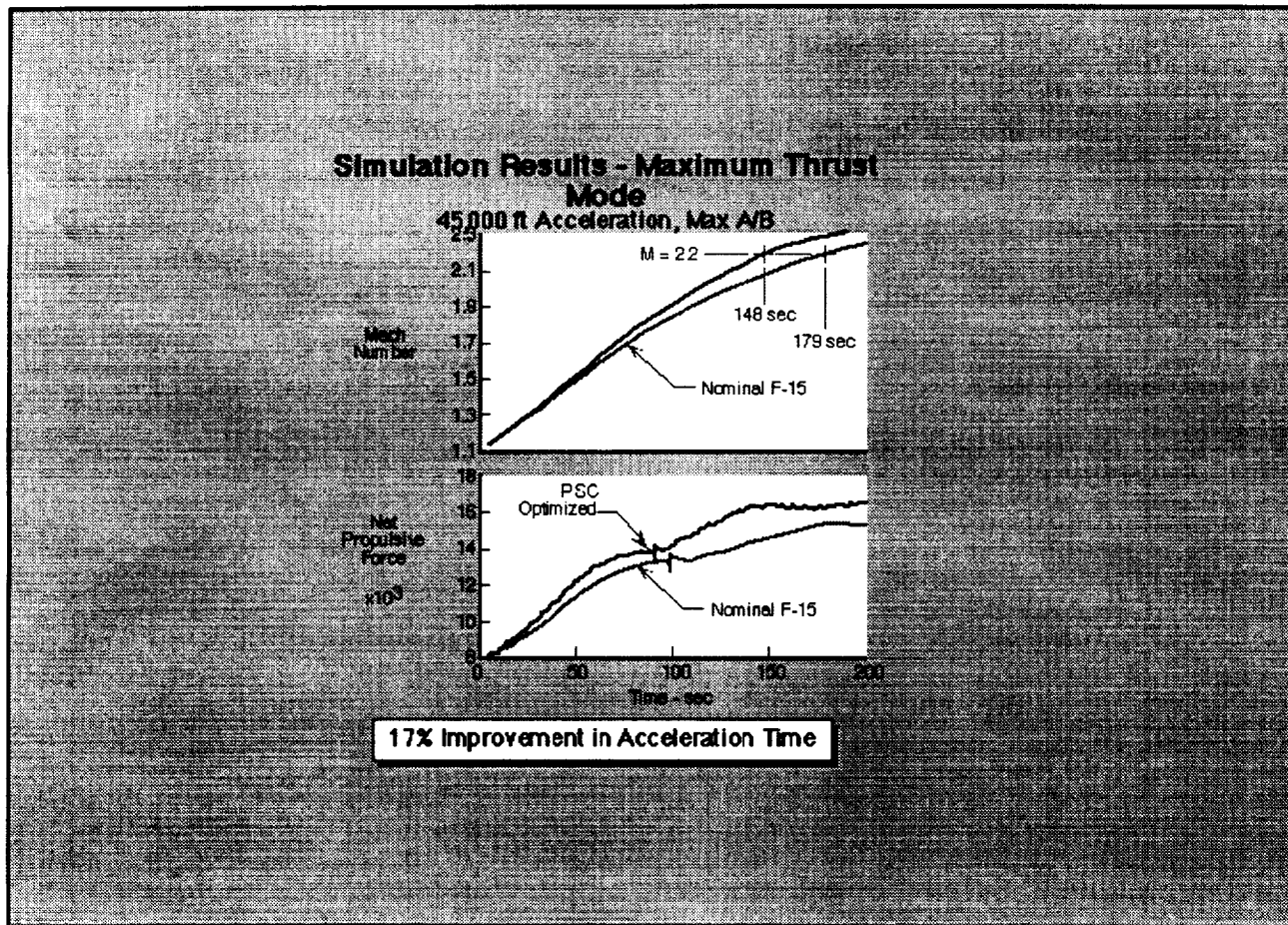
### Prediction of a Maximum Thrust Mode Acceleration

Navigating Around the Workshop:

[\[Workshop Home\]](#) [\[Session Agenda\]](#)

Paper [\[Index / Next\]](#) [\[Submit Response / Read Responses\]](#)

[HELP](#) is Available



In the Maximum Thrust Mode, net propulsive force is increased resulting in greater aircraft excess thrust, allowing faster accelerations or greater climb rates. A maximum power acceleration was simulated with the Six Degree of Freedom Simulation. An aircraft with PSC Maximum Thrust Mode engaged accelerates from 1.1 to 2.2 Mach number in 148 seconds where as a baseline aircraft takes 179 seconds. This is a 17% improvement in acceleration time.

Paper [\[Index / Next\]](#) [\[Submit Response / Read Responses\]](#)

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Navigating Around the Workshop:

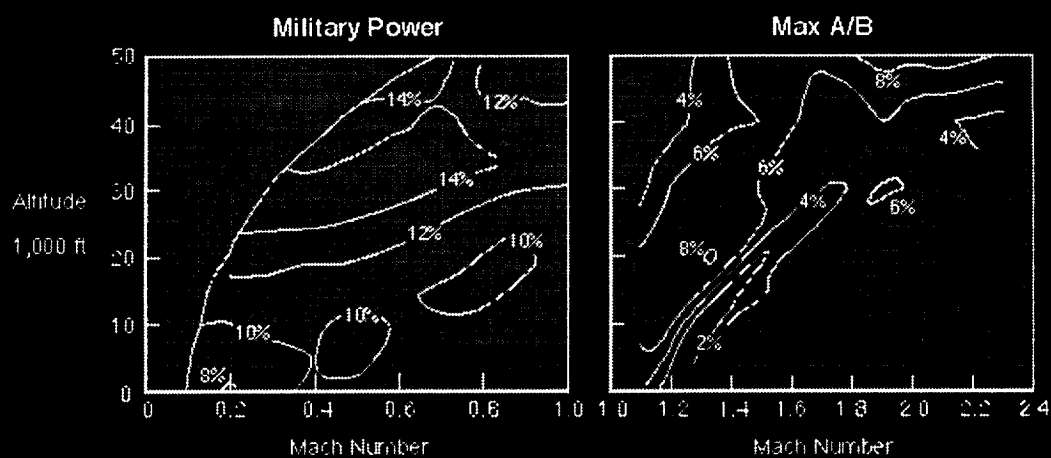
[\[Workshop Home\]](#) [\[Session Agenda\]](#)

Paper [\[Index / Prev / Next\]](#) [\[Submit Response / Read Responses\]](#)

[HELP](#) is Available

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## Predicted Engine Thrust Improvement PSC Maximum Thrust Mode



Thrust improvements of up to 14% at military power and up to 8% at maximum power are predicted for the Maximum Thrust Mode.

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Paper [\[Index / Prev / Next\]](#) [\[Submit Response / Read Responses\]](#)

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### "Maximum Thrust Mode Evaluation", page 3

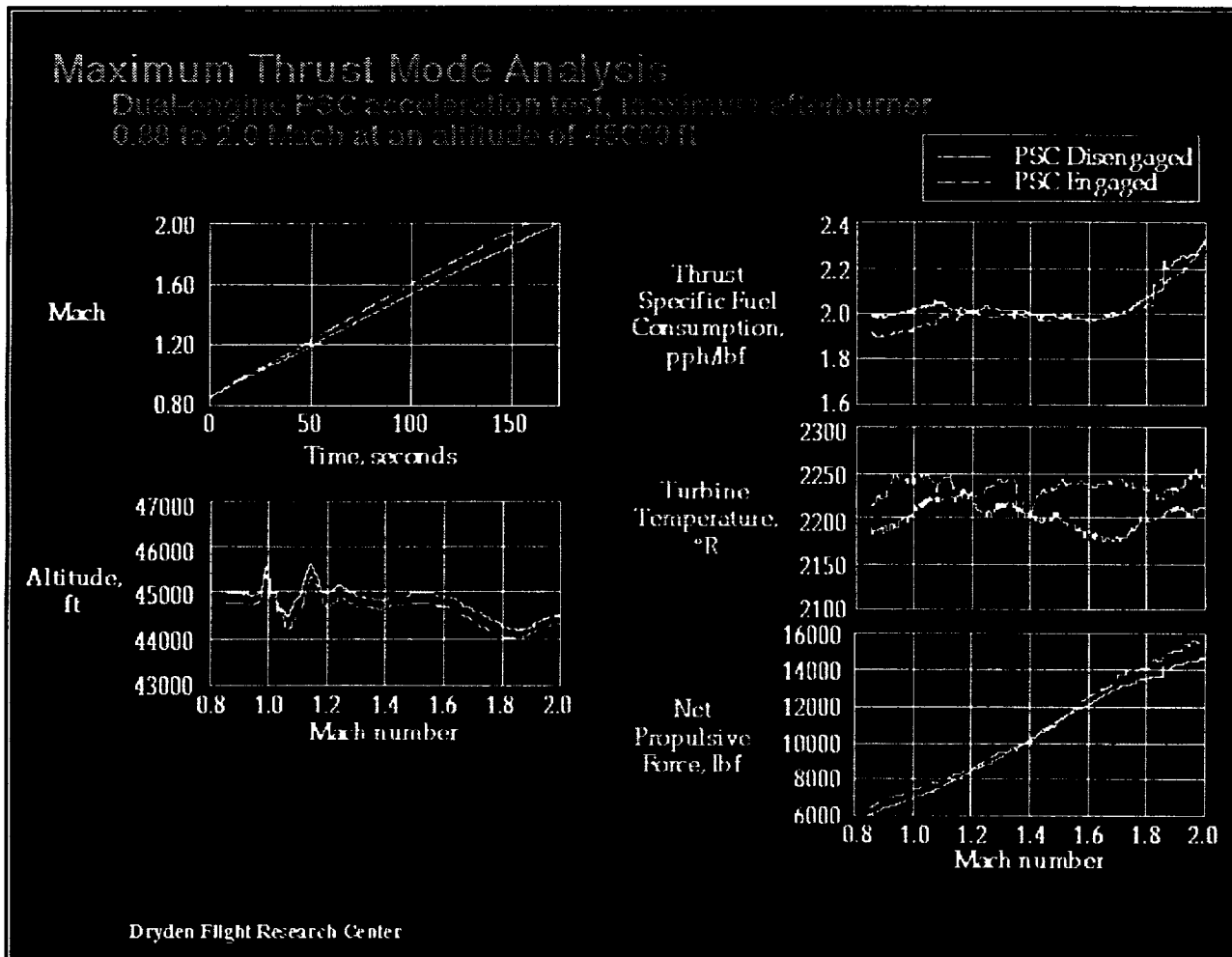
#### Maximum Thrust Mode Analysis

Navigating Around the Workshop:

[\[Workshop Home\]](#) [\[Session Agenda\]](#)

Paper [\[Index / Prev / Next\]](#) [\[Submit Response / Read Responses\]](#)

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The Maximum Thrust mode is designed to maximize Net Propulsive Force, FNP, during accelerations. The test maneuvers were conducted by stabilizing both engines at a given power setting prior to beginning an acceleration. Usually, back to back accelerations were performed through the same air mass with and without the PSC system engaged. This helped to reduce the effect of atmospheric differences on performance when making comparisons between the two runs. In addition, results from comparisons of time to accelerate between separate accelerations were standardized for differences in weight. The Maximum Thrust mode was evaluated at subsonic and supersonic Mach numbers and focused on three altitudes: 15,000, 30,000, and 45,000 feet. Flight data were collected for military rated and maximum afterburning power settings.

Analysis is shown from a single test point demonstration of the PSC Maximum Thrust Mode during the dual-engine test phase. Comparison data of two accelerations performed at 45000 feet from Mach 0.9 to Mach 2.0 with and without use of the PSC Maximum Thrust Mode are plotted. The runs were completed back to back and through the same air mass to minimize the effects of outside influences on the experiment.

such as ambient temperature fluctuations. To further produce a valid comparison, the acceleration times were corrected for weight and temperature differences. Because this was a two engine test, the pilot made no throttle inputs and Mach number was controlled indirectly by the PSC system maximizing Net Propulsive Force (FNP).

Time histories are presented for flight condition (M and altitude), and the left-side propulsion system performance parameters (FNP, FTIT, and TSFC), engine operating parameters (EPR, airflow, variable vane angle, and fan stall margin) and inlet parameters (inlet ramp angles and shock displacement ratio). The right-side propulsion system is characterized by similar results. With the PSC system engaged, the acceleration time was reduced by 14.8 sec or 8.5 percent from the baseline acceleration time.

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Paper [[Index](#) / [Prev](#) / [Next](#) ] [[Submit Response](#) / [Read Responses](#)]

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## NASA Dryden Flight Research Center

"Maximum Thrust Mode Evaluation", page 4

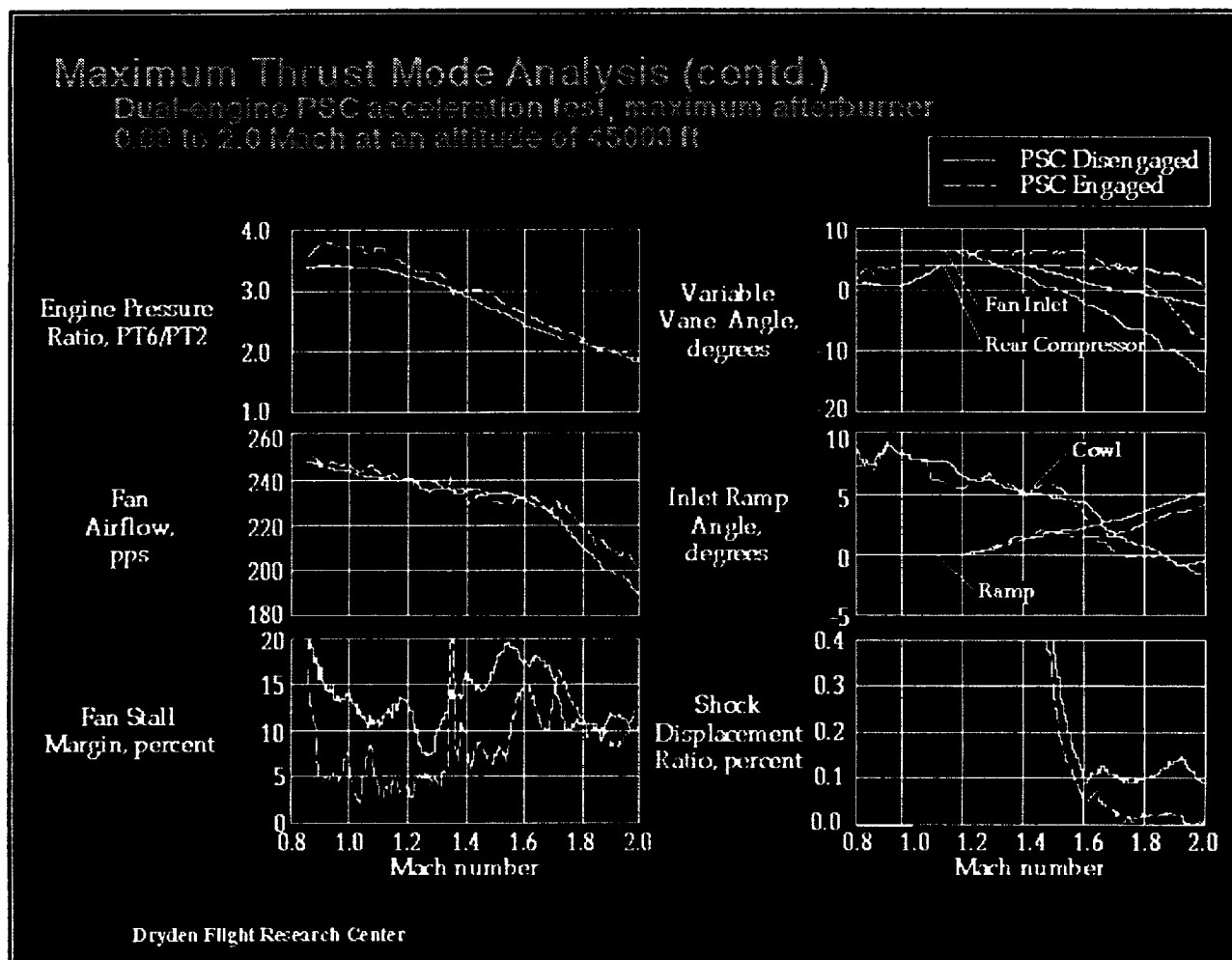
### Maximum Thrust Mode Analysis (contd.)

Navigating Around the Workshop:

[\[Workshop Home\]](#) [\[Session Agenda\]](#)

Paper [\[Index / Prev / Next\]](#) [\[Submit Response / Read Responses\]](#)

[HELP](#) is Available



The manner in which the engines are optimized over the Mach 0.9 to Mach 2.0 range is typical for the maximum thrust mode. For the subsonic and supersonic region below Mach 1.80, the EPR trims contribute the most to increasing FNP; and above Mach 1.80, airflow uptrims command the most FNP increase. The variable vane angles of the fan and compressor are also trimmed to increase compression efficiency. Subsonically, the engine is driven to the minimum allowable fan stall margin. Supersonically, the inlets are driven to the maximum allowable airflow. In addition, PSC trims caused the FTIT to operate at its maximum limit for the entire acceleration.

Paper [\[Index / Prev / Next\]](#) [\[Submit Response / Read Responses\]](#)

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### "Maximum Thrust Mode Evaluation", page 5

#### Summary of Results for the Maximum Thrust Mode

Navigating Around the Workshop:

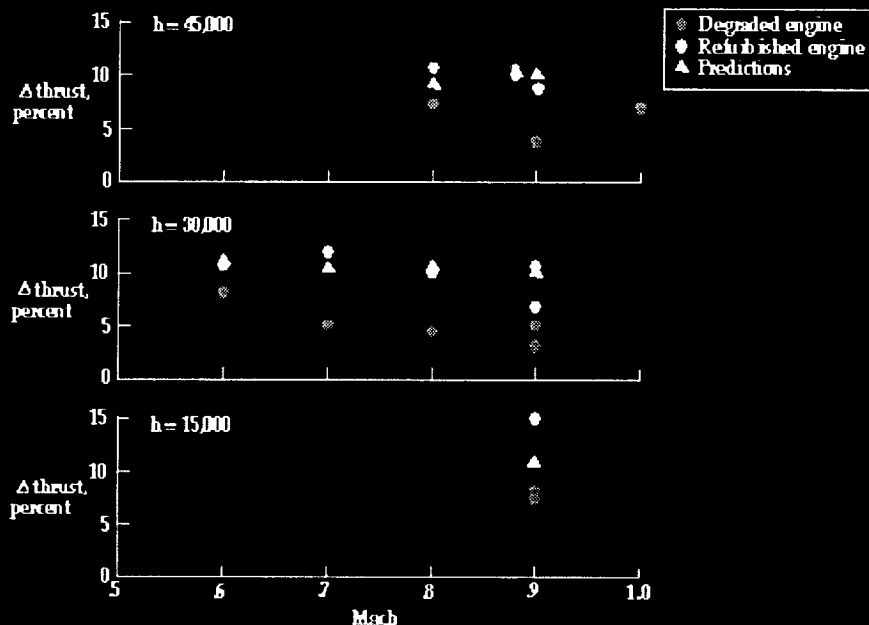
[\[Workshop Home\]](#) [\[Session Agenda\]](#)

Paper [\[Index / Prev / Next\]](#) [\[Submit Response / Read Responses\]](#)

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### Summary of Results for the Maximum Thrust Mode

Predicted and measured net propulsive force increases  
for single-engine subsonic tests



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A comparison of measured and predicted thrust increases produced by the PSC system during single-engine subsonic testing is presented above for the test engine at military power setting as a function of flight condition. Data were collected at 15,000, 30,000, and 45,000 feet altitudes for the refurbished and degraded engines. For the refurbished engine at 30,000 ft, thrust increases average approximately 11 percent as Mach increases from 0.60 to 0.90 and compare very well with predictions. The degraded engine has significantly less thrust increase capability and diminishes with increasing Mach number. This level of thrust increases requires the engine to operate hotter. For the refurbished engine, FTIT in general is below the engine operating limit, with the PSC system engaged or disengaged. However, the degraded engine is operating hotter over the flight envelope to achieve a defined thrust level. In particular, the FTIT limit is generally restricting the amount of additional thrust increase.

The 45,000 ft thrust increase levels and trends are similar to those at 30,000 ft. At the 45,000 ft flight condition not as much data were collected since the aircraft cannot stabilize at the lower Mach numbers. The data are quite limited at 15,000 ft; however the thrust increases for the degraded engine

are low because of the engine temperature limit being reached. At Mach 0.90, the refurbished engine has a thrust improvement of 15 percent, while the degraded engine has approximately half that amount. Overall, the maximum thrust mode performed well at military power and subsonic regime. To completely characterize the benefits of the PSC algorithm for the maximum thrust mode, two-engine performance is of importance since net aircraft performance is a primary interest.

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Paper [[Index](#) / [Prev](#) / [Next](#) ] [[Submit Response](#) / [Read Responses](#)]

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### "Maximum Thrust Mode Evaluation", page 6

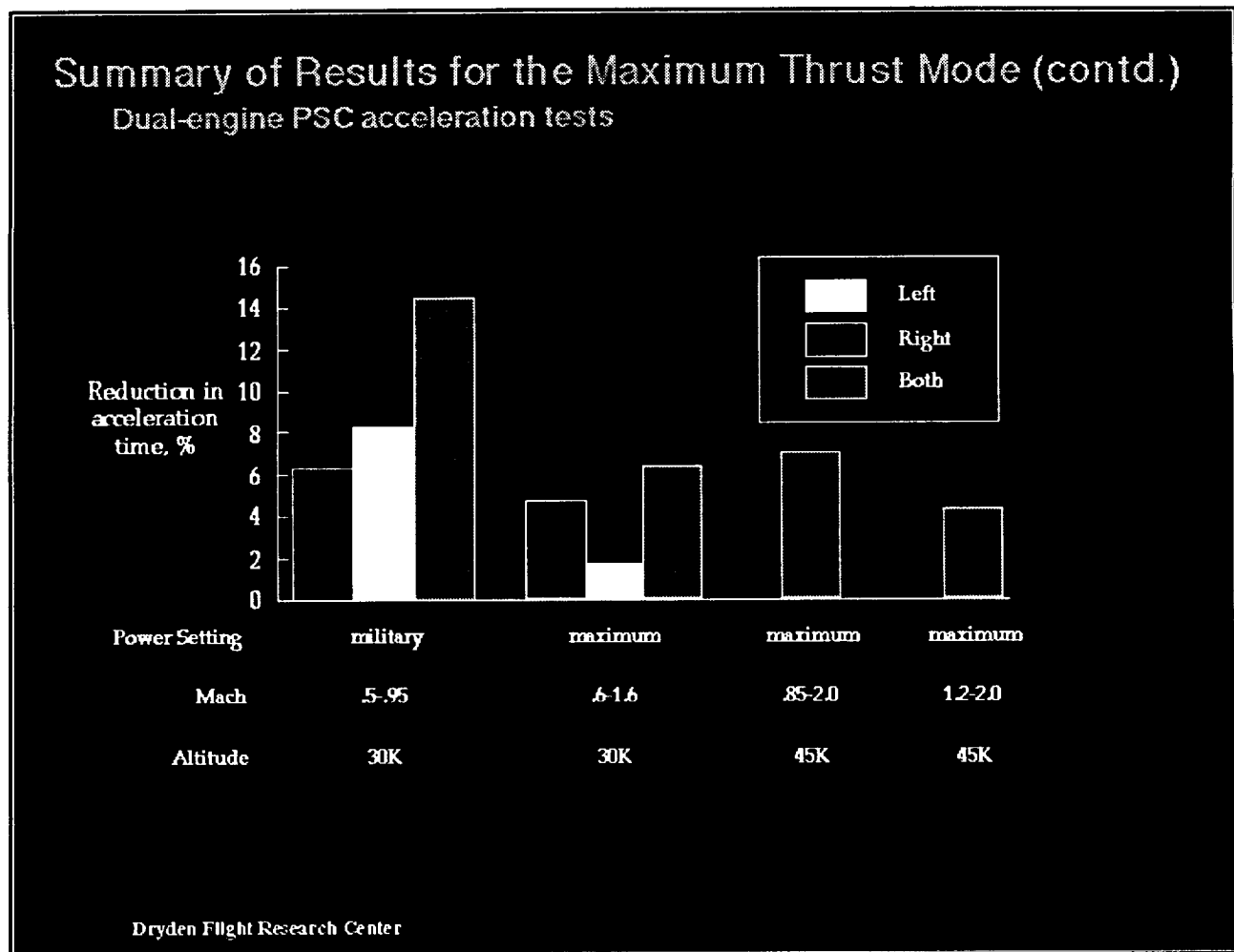
#### Summary of Results for the Maximum Thrust Mode (contd.)

Navigating Around the Workshop:

[\[Workshop Home\]](#) [\[Session Agenda\]](#)

Paper [\[Index / Prev\]](#) [\[Submit Response / Read Responses\]](#)

[HELP](#) is Available



Measured reductions in acceleration times which resulted from the application of the PSC Maximum Thrust mode during the dual-engine test phase is presented **above** as a function of power setting and flight condition. Data were collected at altitudes of 30,000 and 45,000 feet at military and maximum afterburning power settings. The time savings for the supersonic acceleration is less than at subsonic Mach numbers because of the increased modeling and control complexity. In addition, the propulsion system was designed to be optimized at the mid supersonic Mach number range. Recall that even though the engine is at maximum afterburner, PSC does not trim the afterburner for the Maximum Thrust Mode.

Subsonically at military power, time to accelerate from Mach 0.6 to 0.95 was cut by between 6 and 8 percent with a single engine application of PSC, and over 14 percent when both engines were optimized. At maximum afterburner, the level of thrust increases were similar in magnitude to the military power results, but because of higher thrust levels at maximum afterburner and higher aircraft drag at supersonic Mach numbers the percentage thrust increase and time to accelerate was less than for the supersonic accelerations. Savings in time to accelerate supersonically at maximum afterburner ranged

from 4 to 7 percent.

In general, the Maximum Thrust mode has performed well, demonstrating significant thrust increases at military and maximum afterburner power. Increases of up to 15 percent at typical combat-type flight conditions were identified. Thrust increases of this magnitude could be useful in a combat situation.

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Paper [[Index](#) / [Prev](#) ] [[Submit Response](#) / [Read Responses](#)]

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